ELECTRON MOBILITY IN A MAGNETIC FIELD

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ABSTRACT. The values of electron mobility in air in presence of a magnetic field varying from 0 to 200 Gauss and over a wide range of pressure have been computed from break-down measurements. The validity of the expression $\mu/\mu_H = (1+C_1H^2/P^2)$ deduced by Townsend and Gill (1938) and also by Blevin and Haydon (1958) has been tested by plotting μ/μ_H against $1/p^2$ and the curve is a straight line for a limited range of pressure above .125 m.m. of Hg. The constant C_1 is found to decrease with the increase of the magnetic field and the curve of C_1 against H is parabolic in nature. An analytical expression has been deduced which explains the observed variation to a first approximation.

INTRODUCTION

It was shown by Townsend and Gill (1938) that the mobility of the electrons in the direction of the field in presence of a magnetic field is reduced and is given by

$$\mu_H = \frac{\mu}{1+\omega_H{}^2\tau^2} \qquad \dots \quad (1)$$

where τ is the time between two successive collisions and $\omega_H = eH/mc$. Blevin and Haydon (1958) considering the bulk properties of electron avalanches have deduced that

$$\mu_H = \frac{\mu}{1+C_1.H^2/P^2} \qquad \dots \quad (2)$$

where $C_1 = \left[\frac{e}{m}\cdot\frac{L}{u}\right]^2$, L denoting the mean free path of the electron in the gas at a pressure of 1 m.m. of Hg and u denotes the random velocity of the electrons in the gas. It can easily be shown that equation (1) reduces to equation (2) if a simple calculation be carried out; from equation (2) it is seen that

$$\mu/\mu_H = 1+C_1H^2/P^2.$$

and if the values of μ/μ_H be plotted against $1/P^2$, for a constant value of the magnetic field then the curve should be a straight line and the intercept of the curve with the axis along which μ/μ_H has been plotted should be numerically equal to unity while the slope of the curve should provide the value of the constant C_1. The object of this note is to verify equation (1) or (2) so as to determine the range of pressure over which it is valid and to see whether C_1 is a constant over the range of magnetic field investigated.

METHOD OF COMPUTATION OF MOBILITY

In our preliminary note we have not made any experimental measurement of mobility which we propose to undertake very soon. Unfortunately we have not come across in the literature any data for the measurement of mobility in a magnetic field. Sen and Ghosh (1962) determined the breakdown potential in air in presence of a magnetic field varying from 0 to 200 gauss and over a wide range of pressure. If E denotes the breakdown potential per unit length then the random velocity u can be calculated from the relation

$$\tfrac{1}{2}\, mu^2 = eE$$

and the drift velocity of the electrons can be determined from the relation

$$v = (K)^{\frac{1}{2}}/u.$$

where $$K = (2m/M)$$

where m is the mass of the electron and M is the mass of the positive ion. (Von Engel (1959). That this method of calculating the dirft velocity of electrons is reasonably accurate is evident because the same order of drift velocity has been obtained as is found in the literature. In presence of magnetic field also the same procedure of calculating the drift velocity from breakdown potentials has been adopted.

DISCUSSION AND RESULTS

The values of μ/μ_H have been plotted against $1/P^2$ in fig. 1 for different values of the magnetic field. The curve is a straight line for pressures above .125 mm of Hg and below this value it bends down in each case with a negative slope. The

TABLE I

Magnetic field in Gauss	$C_1 \times 10^7$
20	6.02
30	3.80
50	1.60
100	.66
150	.41
200	.52

intercepts made by the curves are different for different values of the magnetic field and lies between 1.0 to 1.1. The values of C_1 as calculated for different curves are entered into Table I.

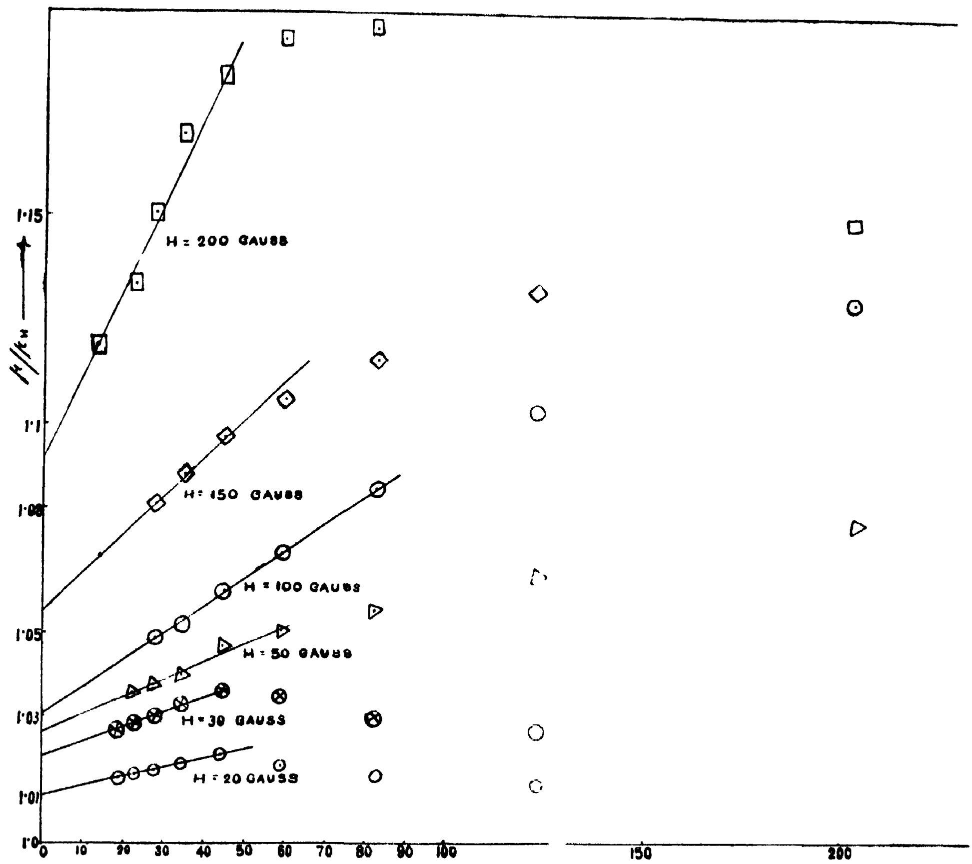

Fig. 1. $1/\rho^2 \rightarrow$

From Table I it is evident that C_1 as deduced from the curves is not a constant but decreases with the increase of the magnetic field and the average value as deduced by Sen and Ghosh (1962) namely 7.464×10^7 is greater than the highest value obtained here. The values of C_1 calculated from different curves have been plotted against the corresponding values of the magnetic field and the curve is parabolic in nature. Haydon (1961) has also reported different values of C_1 for Hydrogen by plotting α_H/α_0 where α is the first Townsend coefficient against values of (H/E) varying from 0 to 2.5. From this result he has concluded that possibly drift velocity is a linear function of (E/P) for small (E/P) values but varies as $(E/P)^n$ where $n > 1$ for larger values of (E/P). An attempt has been made here to explain the variation of C_1 with with H. We have

$$C_1 = \left[\frac{e}{m} \cdot \frac{L}{u_H} \right]^2 = A/u_H^2$$

where A is a constant, and u_H is the random velocity of electrons in presence of a magnetic field. That the random velocity of electrons varies in presence of magnetic field is evident from the fact that the electron temperature which is a measure of the random velocity varies in a magnetic field also . Hence

$$C_1 = \frac{AK}{v_H^2} \text{ where } K = (2m/M)$$

$$= \frac{a'}{v_H^2} \quad \text{where } a' \text{ is another constant.}$$

and it has been pointed out by Blevin and Haydon

$$v_0/v_H = [1+C_1H^2/P^2].$$

$$\therefore \quad C_1 = \frac{a'[1+C_1\cdot H^2/P^2]^2}{v_0^2} = a[1+C_1\cdot H^2/P^2]^2 \text{ where } a = a'/v$$

$$\therefore \quad C_1 = \frac{[1-2a\cdot H^2/P^2] \pm \sqrt{(2a\cdot H^2/p^2-1)^2 - 4a^2H^4/P^4}}{2aH^4/P^4}$$

$$= \frac{[1-2a\cdot H^2/P^2] \pm \sqrt{1-4aH^2/P^2}}{2aH^4/P^4}$$

$$\approx \frac{P^2}{H_2}\left\{\frac{P^2}{aH^2}-2\right\}$$

which shows that the value of C_1 should decrease with the increase in magnetic field. The nature of the curve in Fig. 2 shows that for values of magnetic field

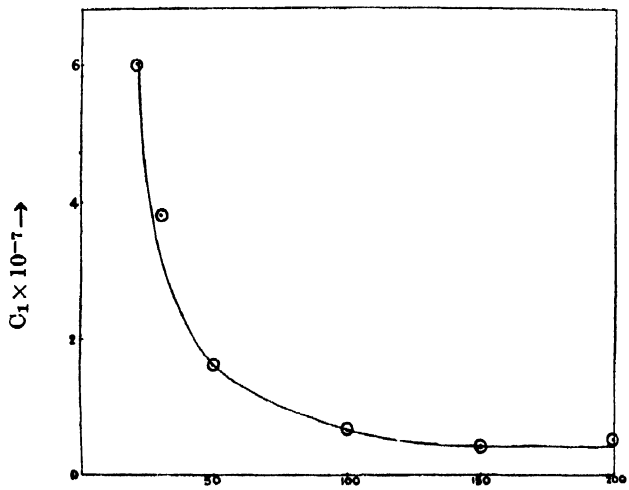

Fig. 2. H in gauss →

greater than 100 gauss, the value of C_1 tends to assume a constant value where as for smaller values of magnetic field it is very susceptible to change for small changes in the magnetic field.

In conclusion it may be stated that the expression for mobility of electrons in a magnetic field as deduced either by Townsend and Gill or by Blevin and Haydon is valid for a limited range of pressure above .125 mm of Hg and the constant C_1 becomes a function of the magnetic field, but practically becomes a constant for values of magnetic field greater than 100 gauss. At the same time, it must be borne in mind that the conclusions reached above are derived from computed values of mobility from breakdown measurements, which the authors think are liable to error. A systematic investigation of mobility measurements in presence of a magnetic field has therefore been undertaken and the results will be reported in future.

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